

## **Altimetry with reflected GPS signal: results from a lakeside experiment**

**Cinzia Zuffada, Stephen Lowe, George Hajj, Michael Lough, Robert Treuhaft,  
Lawrence Young, Sien Wu, Mark Smith, Jesse Lerma\***

**Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, CA 90109**

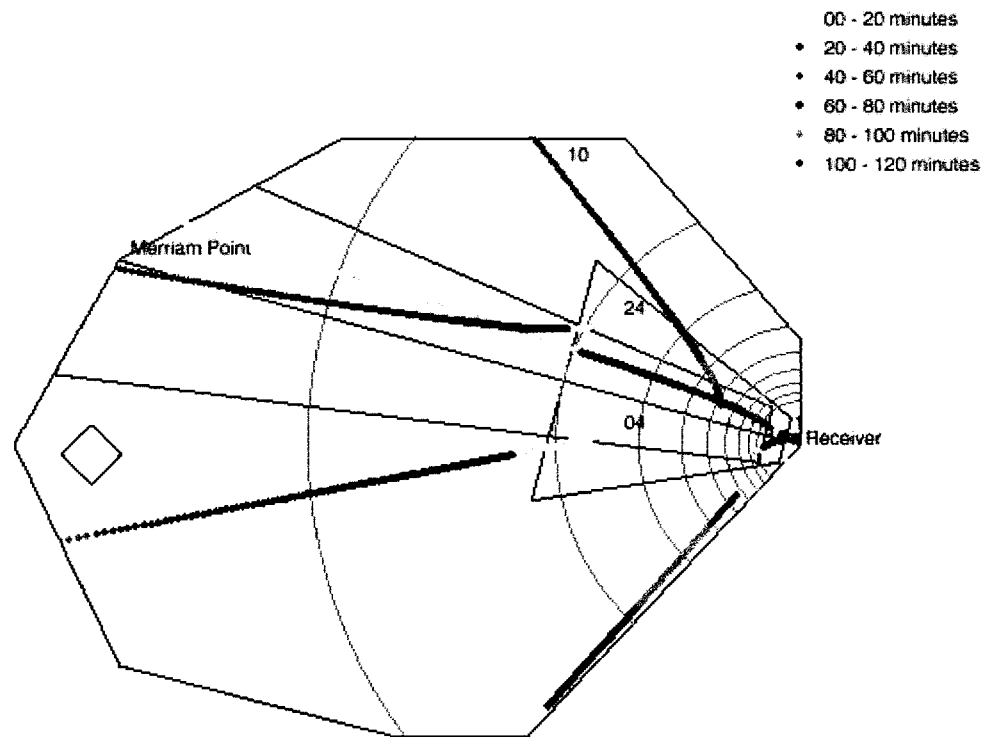
**\*Sony Precision Technology  
La Habra, CA 90631**

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## **OUTLINE**

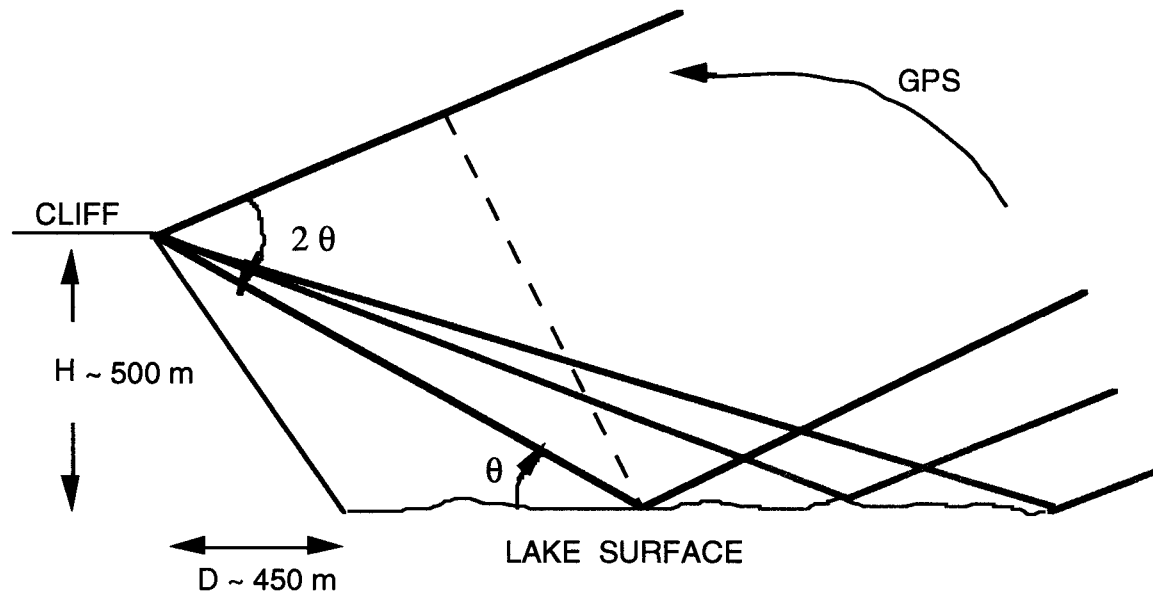
- **EXPERIMENT DESCRIPTION AND RATIONALE**
- **REFLECTION GEOMETRY**
- **EXTRACTION OF OBSERVABLE FROM RAW DATA**
- **PHASE MODEL**
- **HEIGHT DETERMINATION FROM PHASE**
- **PRELIMINARY CONCLUSIONS ON MEASUREMENT ACCURACY**

# DYNAMICS OF GPS REFLECTIONS



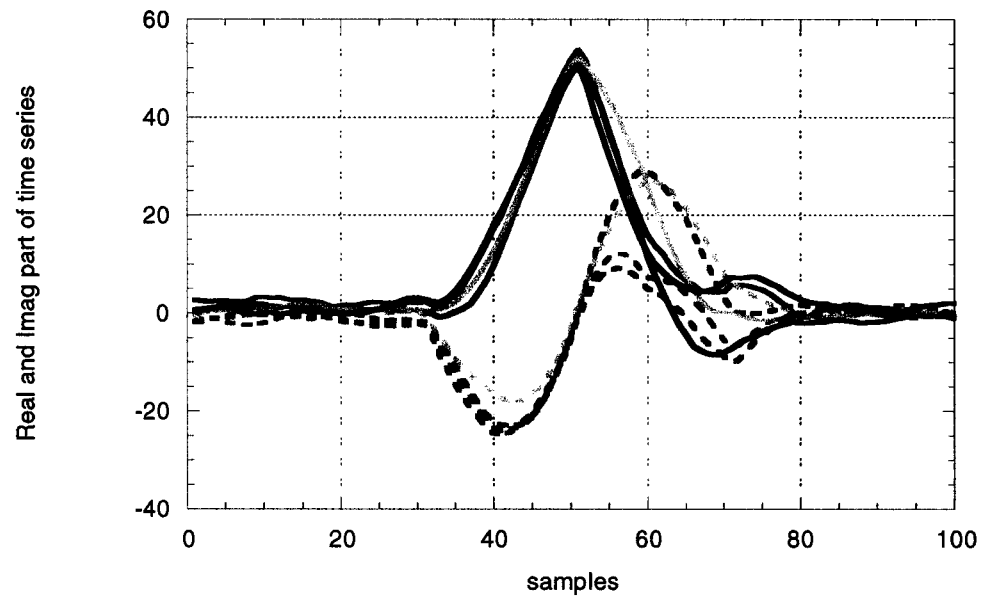
**OCTOBER 7, 1999 PDT 4-6 pm**

## REFLECTION GEOMETRY



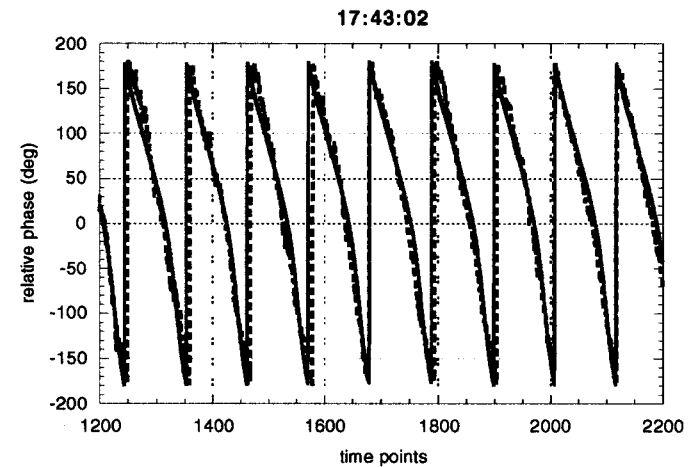
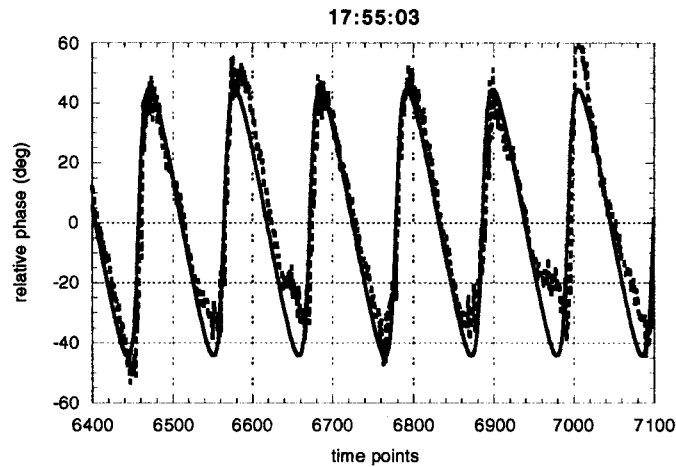
$$\text{PATH DIFFERENCE} = 2 H \sin (\theta)$$

## TYPICAL DATA AFTER COHERENT INTEGRATION COMPLEX TIME SERIES



**NOTE VARIABILITY IN THE REGION OF REFLECTION**

## EXAMPLE PHASE DATA COMPARED WITH PHASE MODEL



**EACH TIME POINT CORRESPONDS TO ONE SPECIFIC 20-MSEC STREAM SHOWN PREVIOUSLY. TIME REFERENCE IS THE BEGINNING OF A DATA FILE**

## PHASE MODEL

- ANALYTICAL MODEL DERIVED FROM IDEAL CORRELATOR SHAPE AND ASSUMPTION OF COHERENT REFLECTION

$$\Phi = ATAN\left(\frac{\frac{A_r \Lambda(t_{r'} - t_r)}{A_d \Lambda(t_{r'} - t_d)} \sin\{\omega(t_{r'} - t_d)\}}{1 + \frac{A_r \Lambda(t_{r'} - t_r)}{A_d \Lambda(t_{r'} - t_d)} \cos\{\omega(t_{r'} - t_d)\}}\right) \quad t_{r'} - t_d < 1chip$$

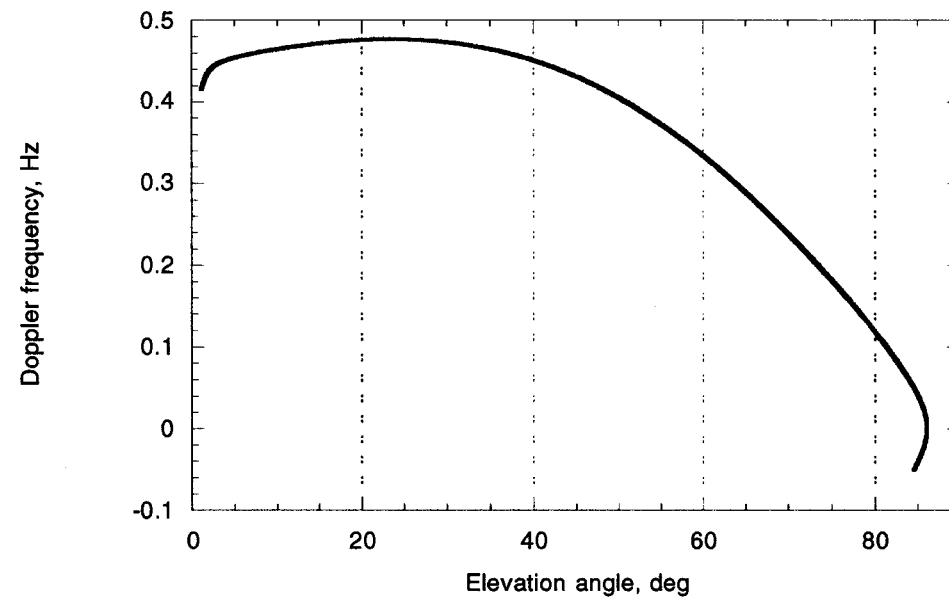
$$\Phi = \tan\{\omega(t_{r'} - t_d)\} \quad t_{r'} - t_d > 1chip$$

$t_d$  = peak time of direct,  $t_r$  = true peak time of reflected,  $t_{r'}$  = estimated peak time of reflected,  $A_d$  = peak amplitude of direct,  $A_r$  = peak amplitude of reflected

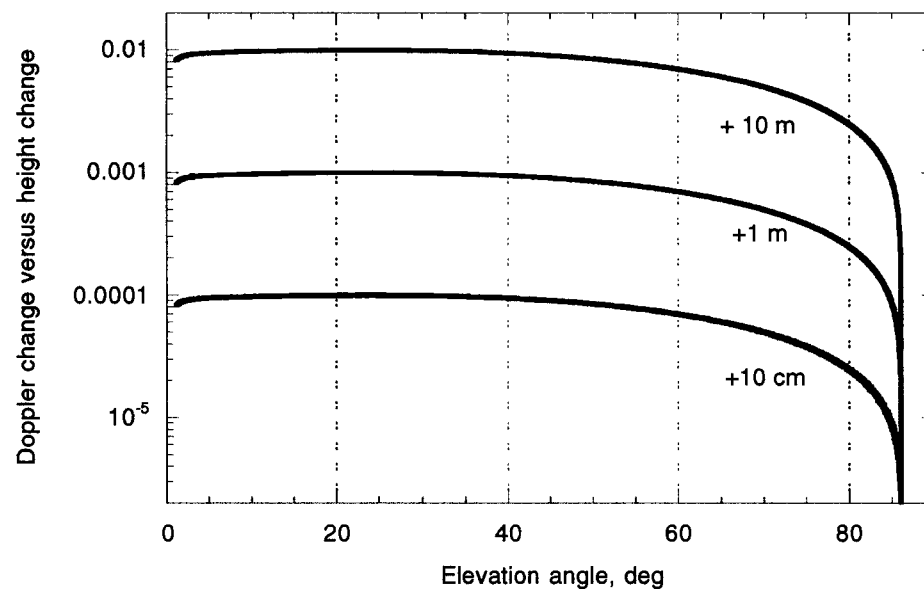
Argument of sin and cos is obtained from the range difference between direct and reflected, assuming a starting time

## DOPPLER MODEL

- THE DERIVATIVE OF THE RANGE DIFFERENCE IS THE DOPPLER

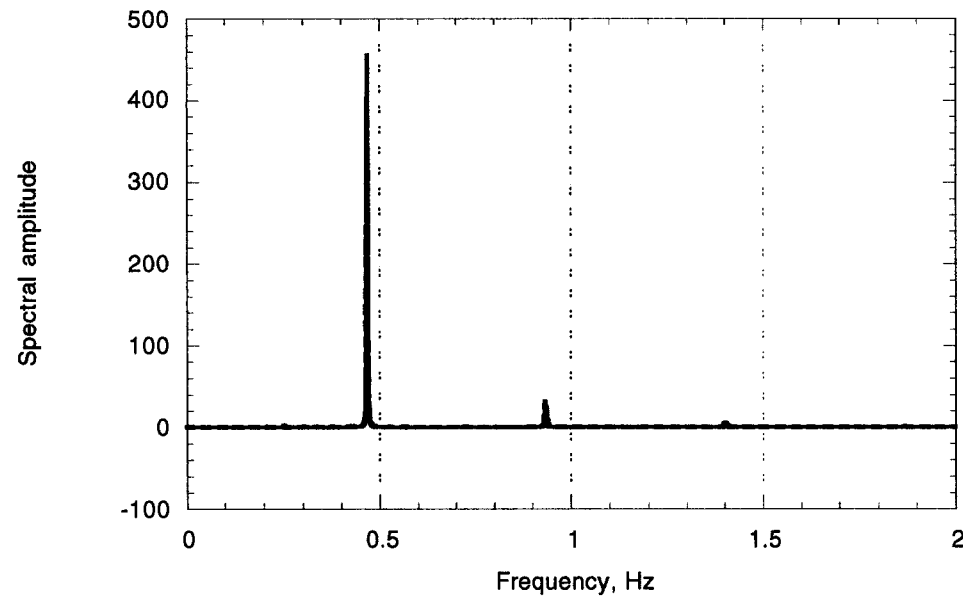


## DOPPLER SENSITIVITY TO HEIGHT



**VARIATION IS RELATIVE TO HEIGHT CHOSEN FOR THE PREVIOUS PLOT, WHICH IN TURN WAS CHOSEN TO MATCH DATA AND MODEL**

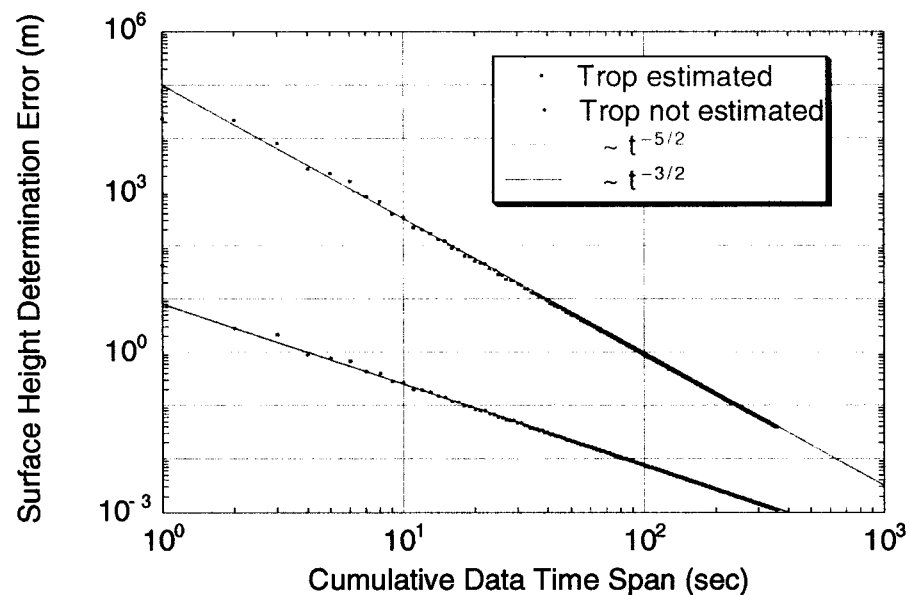
## HEIGHT DETERMINATION FROM DOPPLER



**COMPARISON OF FOURIER TRANSFORM OF DATA AND MODEL,  
CORRECT HEIGHT AND SUFFICIENTLY LONG DATA STREAM WILL  
RESULT IN MATCH TO REQUIRED HEIGHT**

## SURFACE HEIGHT ERROR BEHAVIOR

- FROM PHASE MODEL PARTIALS WE OBTAIN COVARIANCE MATRIX FOR HEIGHT VERSUS DATA NOISE (0.1 RMS)



**CM-LEVEL ACCURACY OBTAINED IN LESS THAN 100 SEC**